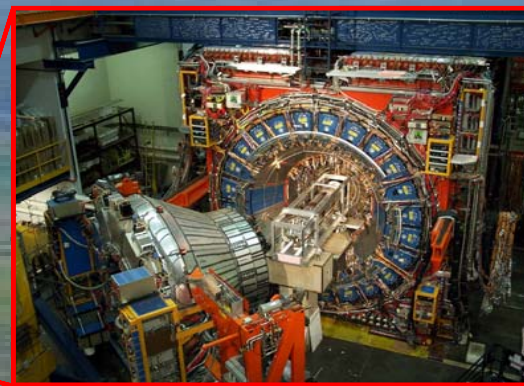
Searches for the Supersymmetric Partner of the Bottom Quark



Carsten Rott, Purdue University
for the CDF Collaboration

Tsukuba, Japan, 2004

Sbottom Searches

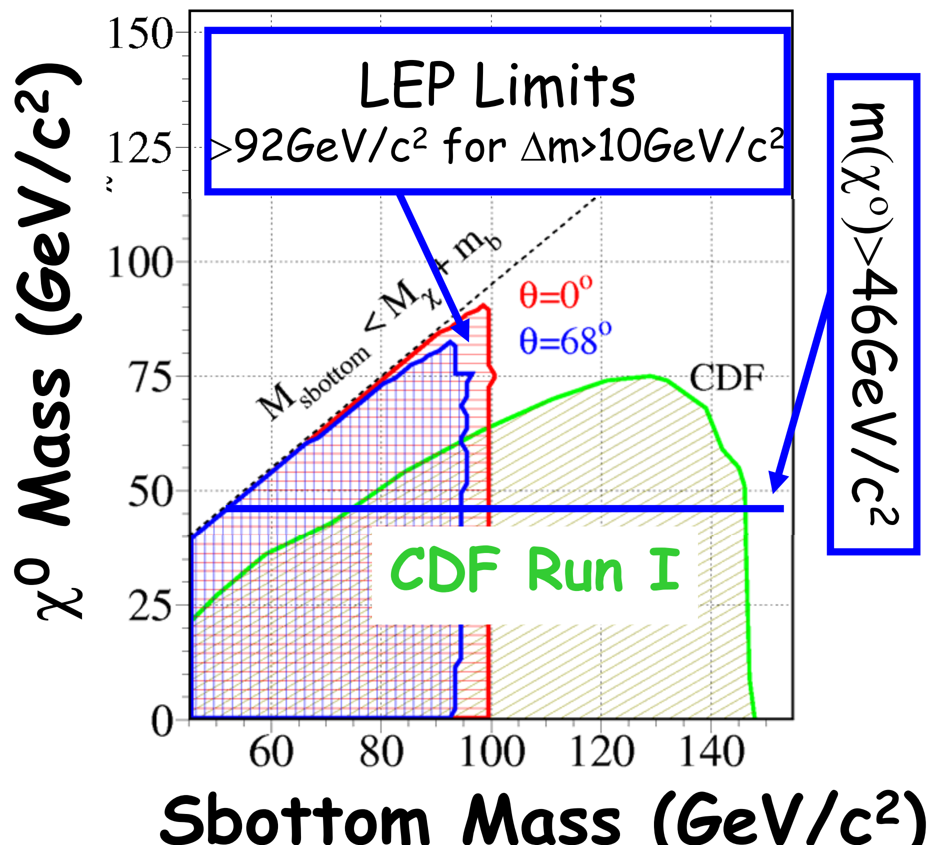
$$m^2_{\tilde{b}_{1,2}} = \frac{1}{2}[m^2_{\tilde{b}_L} + m^2_{\tilde{b}_R} \mp \sqrt{(m^2_{\tilde{b}_L} - m^2_{\tilde{b}_R})^2 + 4m^2_b(A_b - \mu \tan\beta)^2}]$$

Sbottom could be light due to large mass splitting between the eigenstates (large tanβ)

Assume:

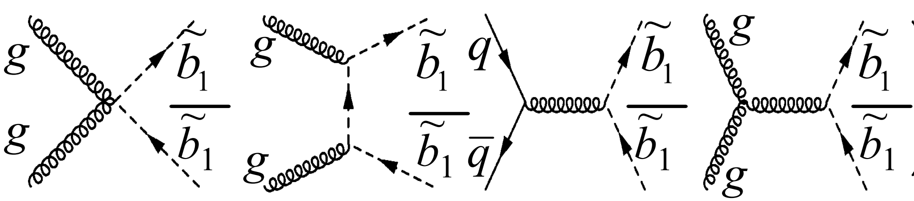
- $BR(\tilde{b}_1 \to b\tilde{\chi}^0_1) = 100\%$
- R-parity conservation which leads to stable undetectable neutralino

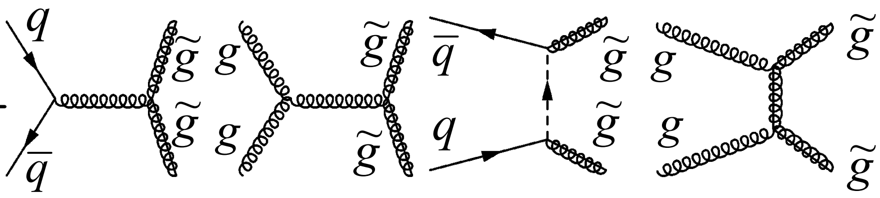
Direct Sbottom Search

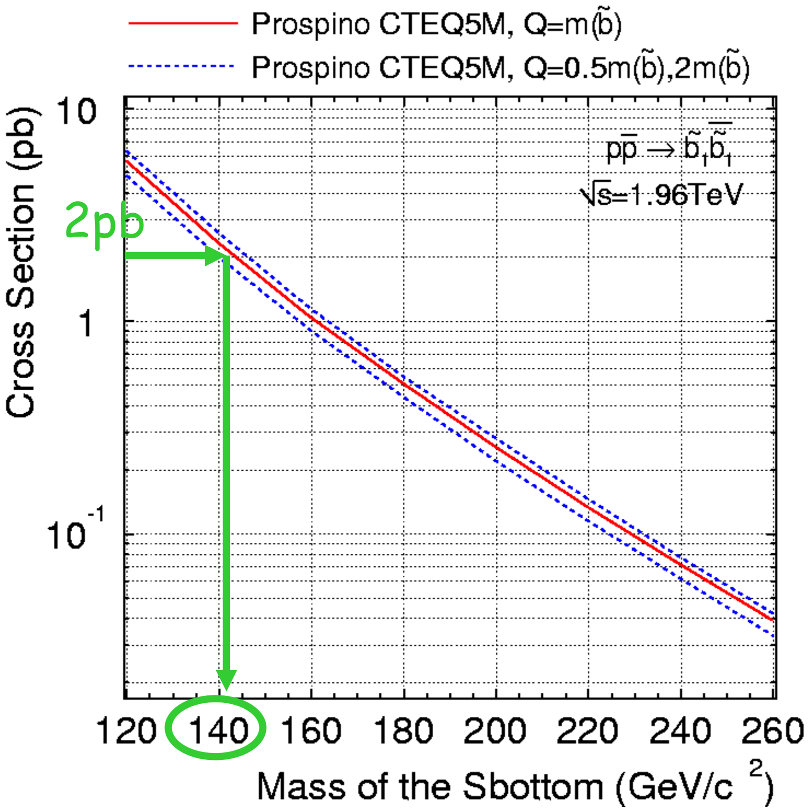


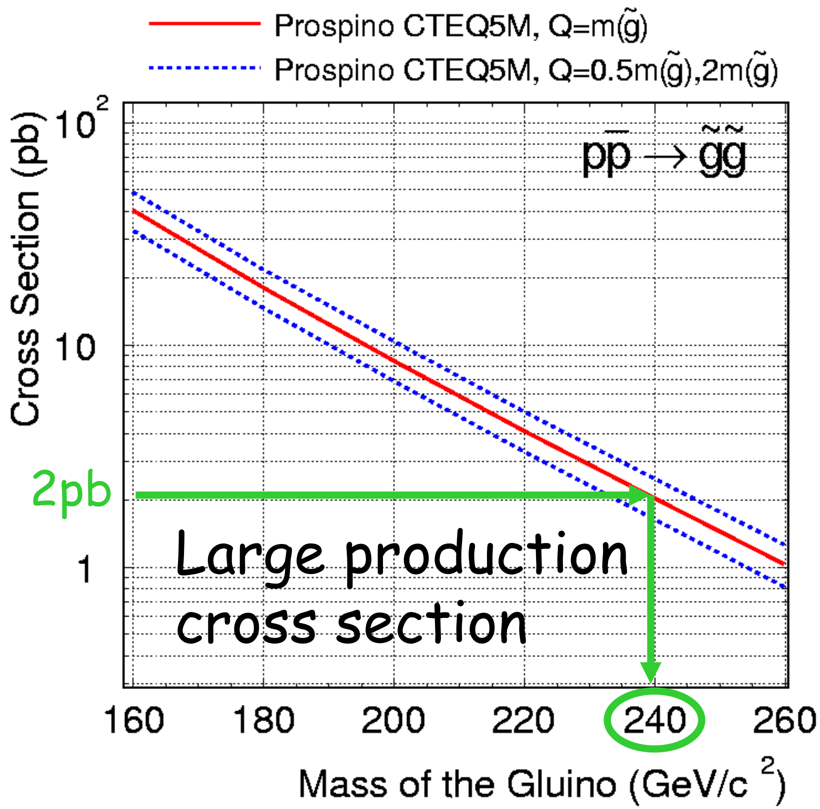
Sbottom Quark Production at the Tevatron

Direct Sbottom production: Gluino-pair production:



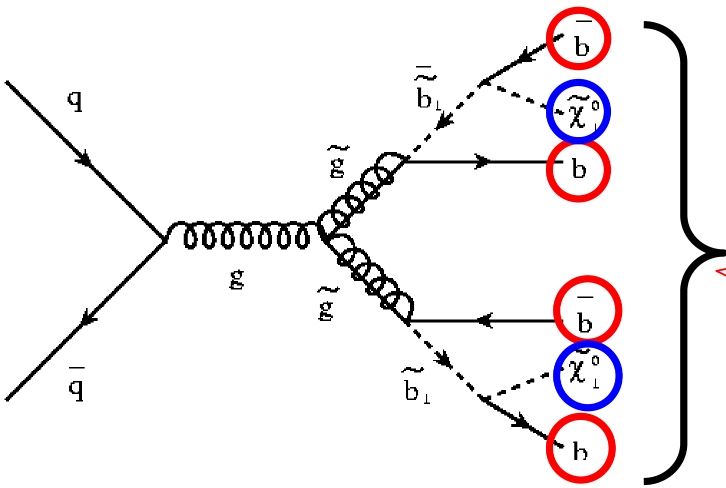






Sbottom Quarks from Gluino Decays Signature

Sbottom quarks could be pair produced at the Tevatron or in a scenario where the gluino is heavier than the sbottom, through decays of gluinos. Consider here search for second case, it yields a richer signature



4 b jets + $\not{E}_T$

$$\tilde{g}\tilde{g} \to (b\tilde{b}_1)(b\tilde{b}_1) \to (bb\tilde{\chi}_1^0)(bb\tilde{\chi}_1^0)$$

Assume:

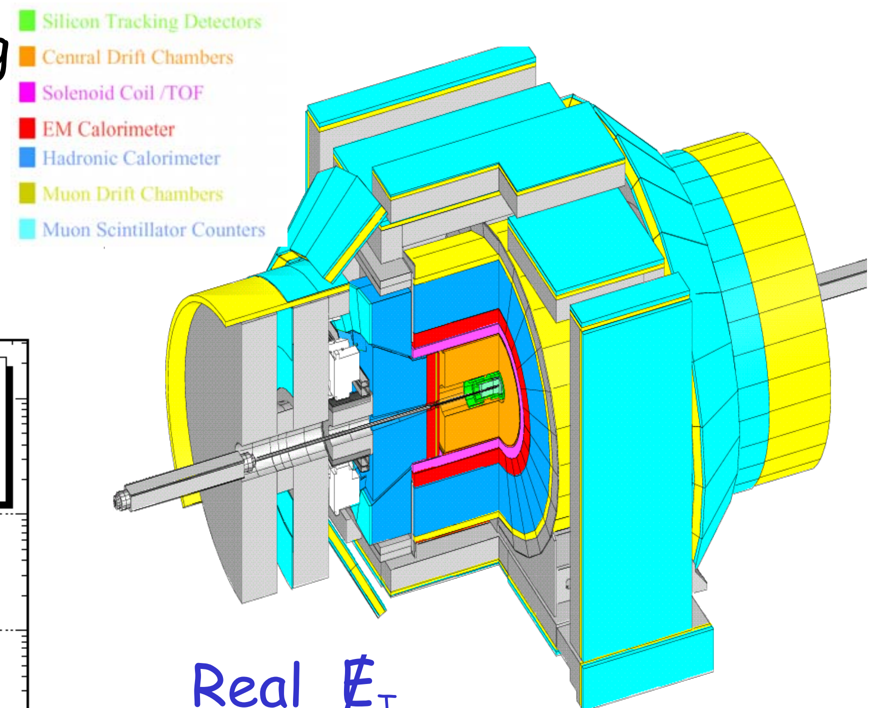
- $m_{\tilde{g}} > m_{\tilde{b}} > m_{\tilde{\chi}_1^0}$
- $m_t + m_{\tilde{\chi}_1^+} > m_{\tilde{b}_1} > m_{\tilde{\chi}_1^0}$
- $BR(\tilde{b}_1 \to b\tilde{\chi}_1^0) = 100\%$

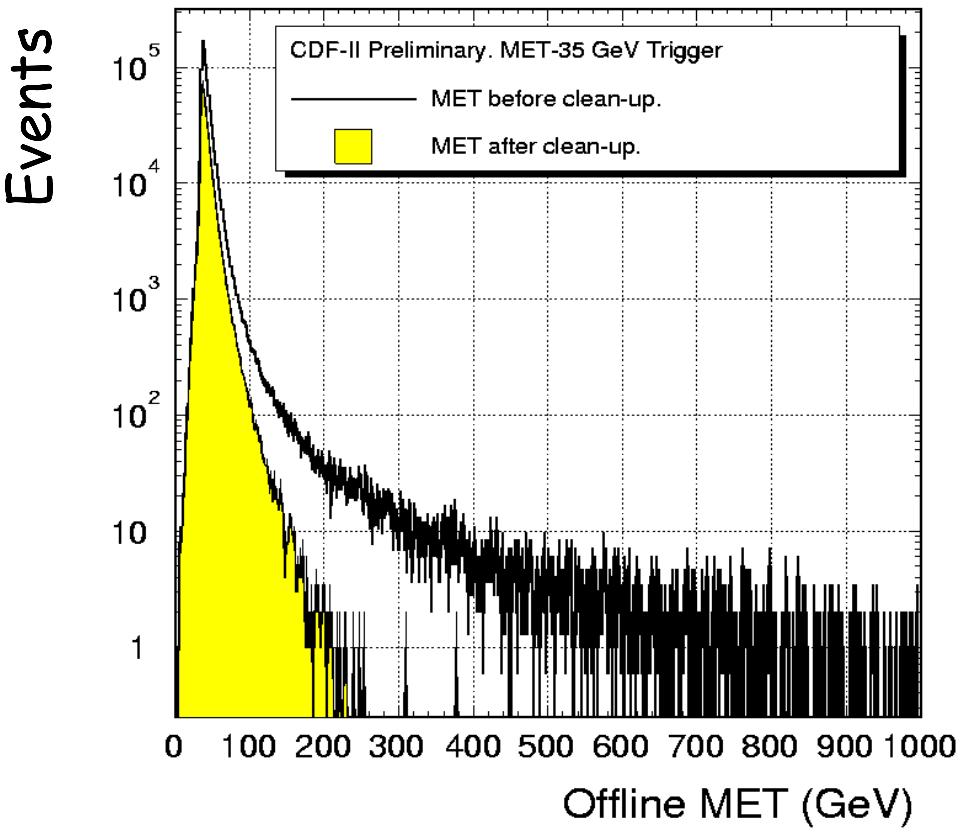
Motivation

- Large cross section
- Very distinctive signature
- Accessible at Tevatron

$\not{E}_T$ at CDF

$\not{E}_T$ caused by particles escaping detection or by detector mis-measurement





Real $\not{E}_T$

from non-detectable

$\nu, \tilde{\chi}_1^0, \ldots$

Fake $\not{E}_T$

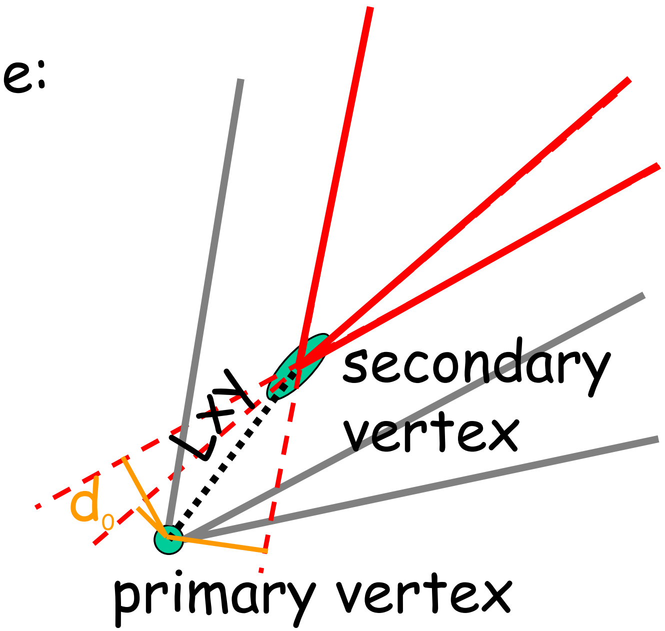
- limited detector coverage
- reconstruction
- cosmics

B-Tagging at CDF

B hadrons fly macroscopic distance:

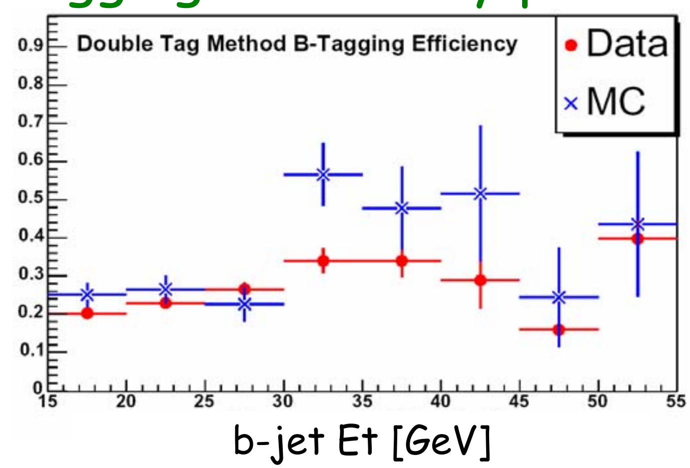
$\Delta L = c\tau \cdot \beta\gamma$ with $c\tau \approx 450\,\mu m$

Can be detected using CDFs Silicon Vertex Detector



b-jets are identified using a secondary vertex tagging algorithm.
Tracks with large impact parameter d_0 are selected and a vertex fitting algorithm is used to reconstruct a displaced vertex.

B-tagging Efficiency per Jet



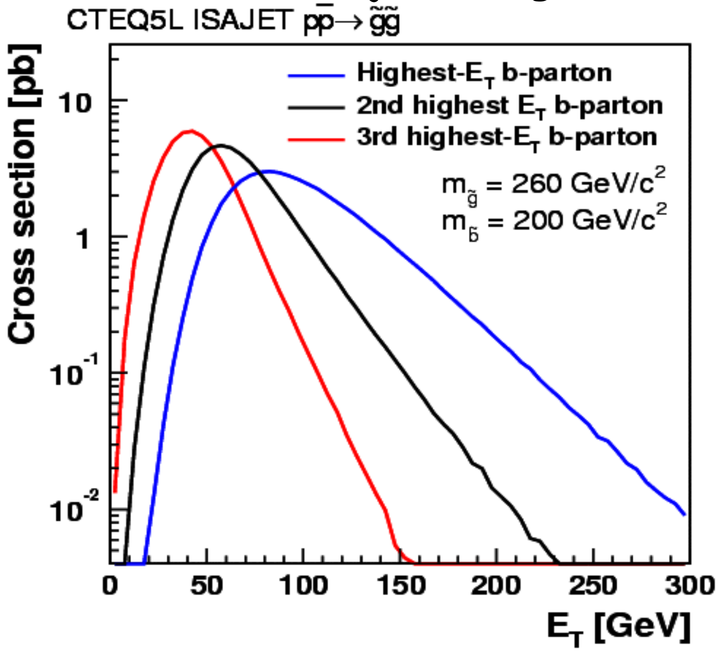
Search Strategy

Event kinematics depend on the mass differences:

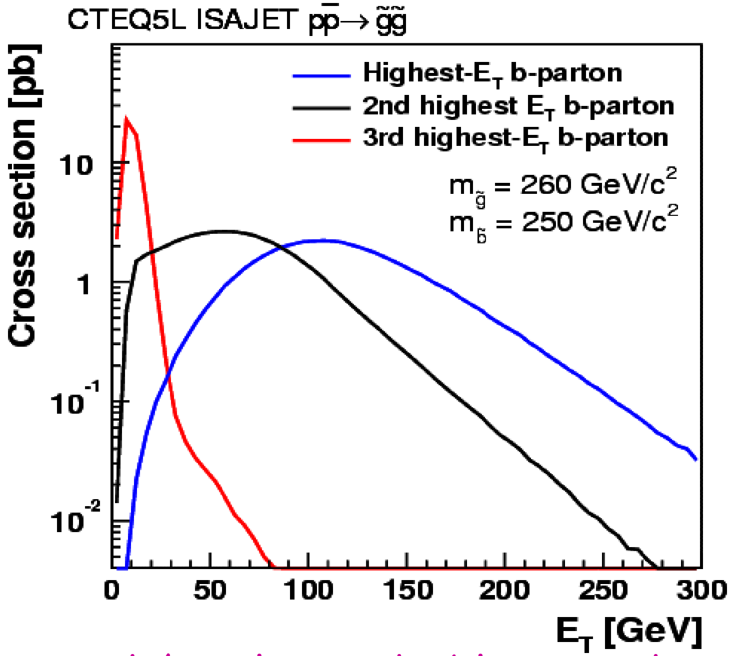
ΔM=m(gluino)-m(sbottom) / Δm=m(sbottom)-m(neutralino)

Assume fixed neutralino mass (60GeV/c^2), Δm is large and consider different gluino/sbottom mass scenarios:

ΔM – large -> b from gluino energetic
χ boosted -> moderate $\not{E}_T$
3rd b-jet energetic



ΔM – small -> b from sbottom decay energetic
χ not boosted -> larger $\not{E}_T$
3rd b-jet non-energetic



Perform separate two analyses: Excl. single tagged / Inclusive double tagged

Backgrounds

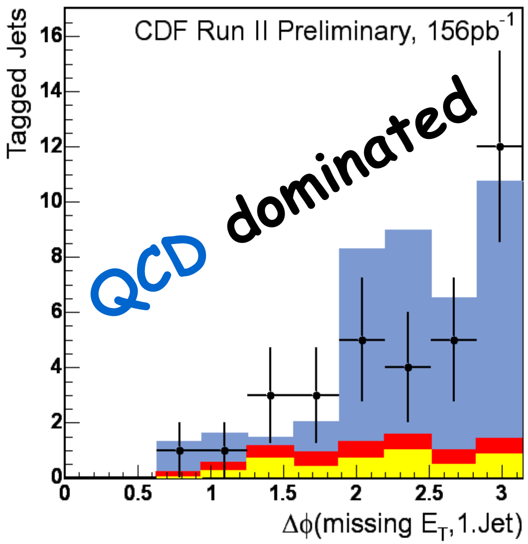
Backgrounds		Description	Reduction
QCD Fake tag rate parameterization from data + QCD HF MC	$b\bar{b}, c\bar{c}, q\bar{q}$	• QCD heavy flavor production • mismeasured jet energy • semileptonic b-decay • σ large	• $\Delta\phi(\not{E}_T$,jets) cuts
W/Z+jets MC simulation	$W \to l\nu$ $Z \to ll, \nu\nu, b\bar{b}$	• mismeasured jet energy • neutrinos	• isolated lepton veto • b-tag requirement
Diboson MC simulation	$W \to l\nu$ $Z \to ll, \nu\nu, b\bar{b}$	• neutrinos • σ small	• isolated lepton veto • b-tag requirement
Top MC simulation	$t \to Wb$, $W \to l\nu$	• b-jets • neutrinos • very similar signature !	• isolated lepton veto

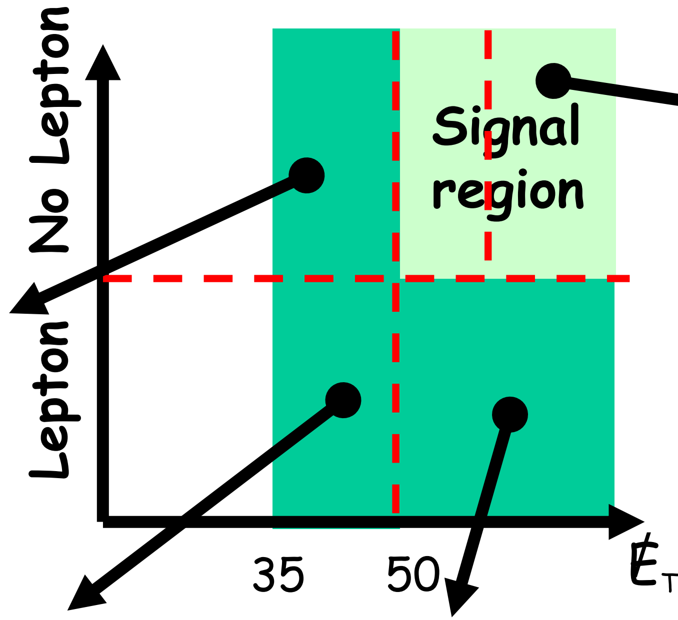
Event selection cuts

- Inclusive three jets Pt>15GeV $|\eta|<2$
- $\not{E}_T > 35$GeV
- $\Delta\phi(\not{E}_T$,1-3jet) > 40^o
- Heavy flavor tags

Use $\not{E}_T$cut and lepton veto/requirement to define signal and control regions

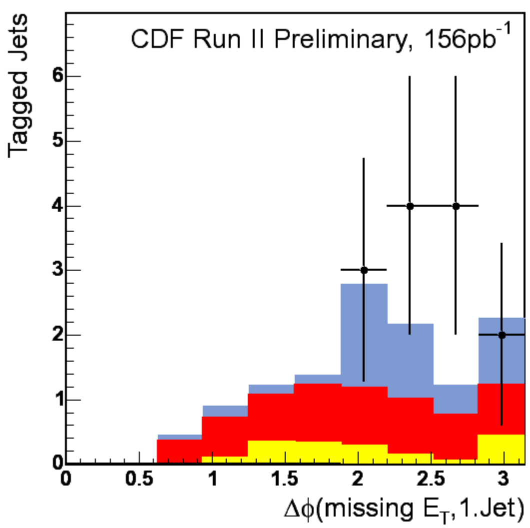
Signal and Control Regions

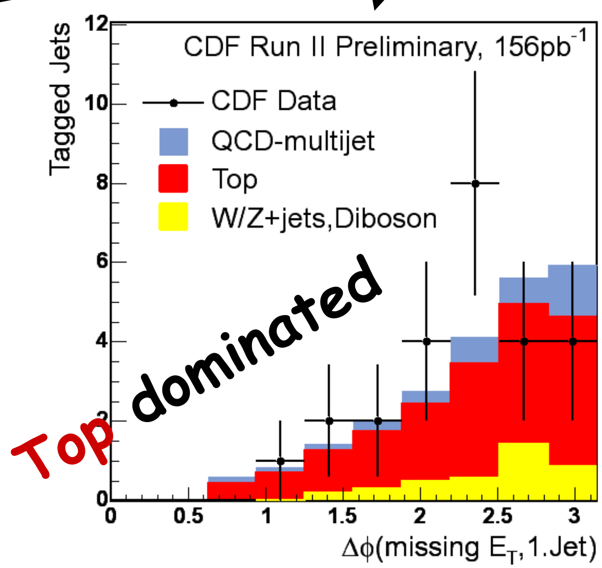




??

Define three control regions, based on $\not{E}_T$ and lepton requirement to provide cross-check for background predictions.





Control regions in agreement with SM predictions

Control Regions

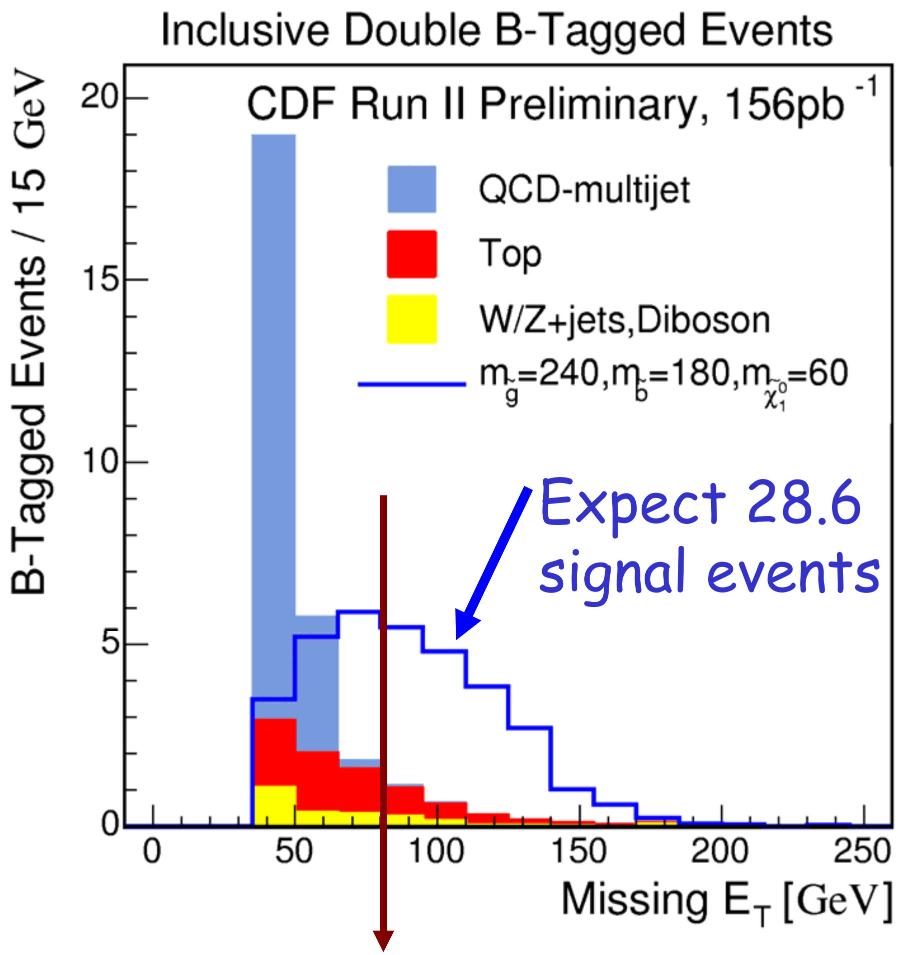
$\not{E}_T$:	35-50GeV	35-50GeV	>50GeV
Lepton:	yes	no	yes
W/Z+jets/Diboson	3.9±0.8	11.0±1.2	9.6±1.2
Top	11.7±0.2	8.2±0.1	35.2±0.3
QCD-multijet	19.2±4.1	129.6±17.3	10.9±4.5
Total background	34.8±4.2	148.8±17.3	55.7±4.7
Data	36	121	63

Statistical errors

Comparison of standard model background predictions for inclusive single tagged events is in agreement with data

Dominant systematics:
- Tagging efficiency
- Energy scale

Signal Expectations



	Exclusive Single B-Tag	Inclusive Double B-Tag
EWK	5.66±0.76±1.72	0.61±0.21±0.19
TOP	6.18±0.12±1.42	1.84±0.06±0.46
QCD	4.57±1.64±0.57	0.18±0.08±0.05
Predicted	16.41±1.81±3.15	2.63±0.23±0.66
Observed	??	??

stat syst

Expected Signal	Acceptance	Expected events
SingleTagged	7.7%	24.3
DoubleTagged	9.0%	28.6

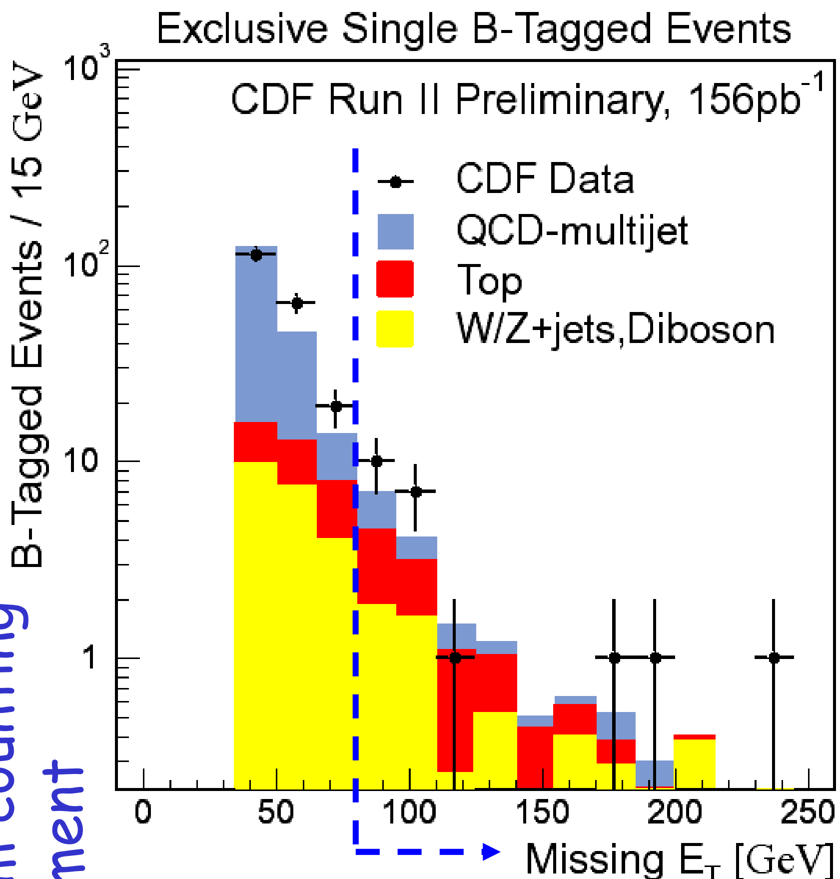
Optimal sensitivity: $\not{E}_T$>80GeV

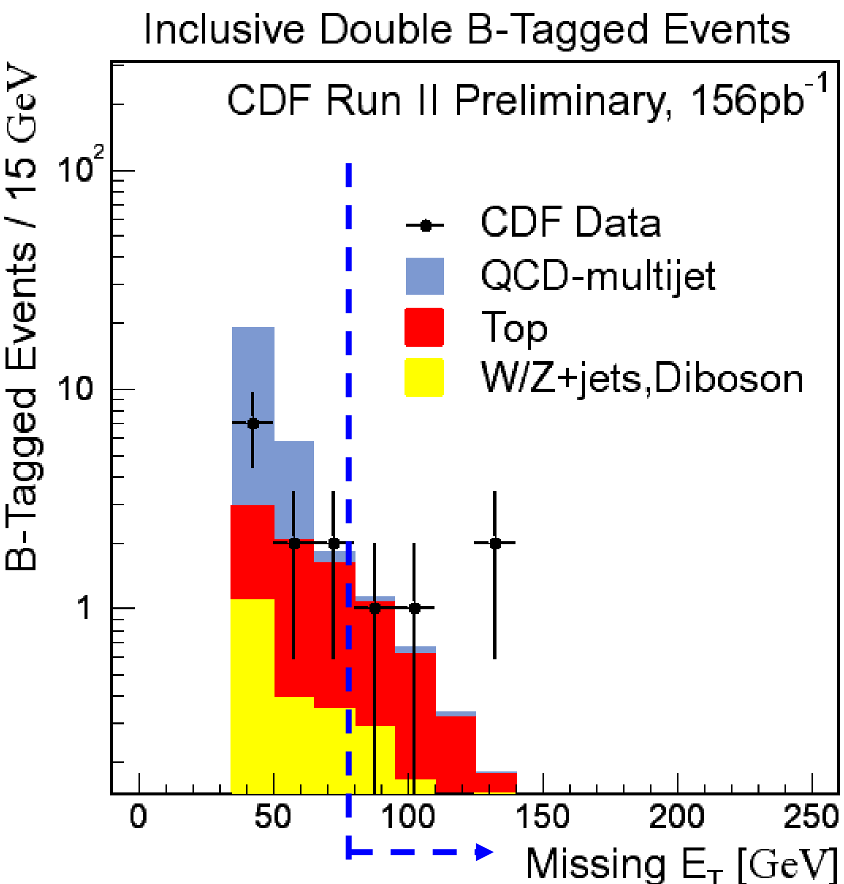
Similar signal acceptance for exclusive single tagged events and inclusive double tagged events

Large signal acceptance + small SM background

Results

Use 156pb^{-1} of data taken 2002-2003



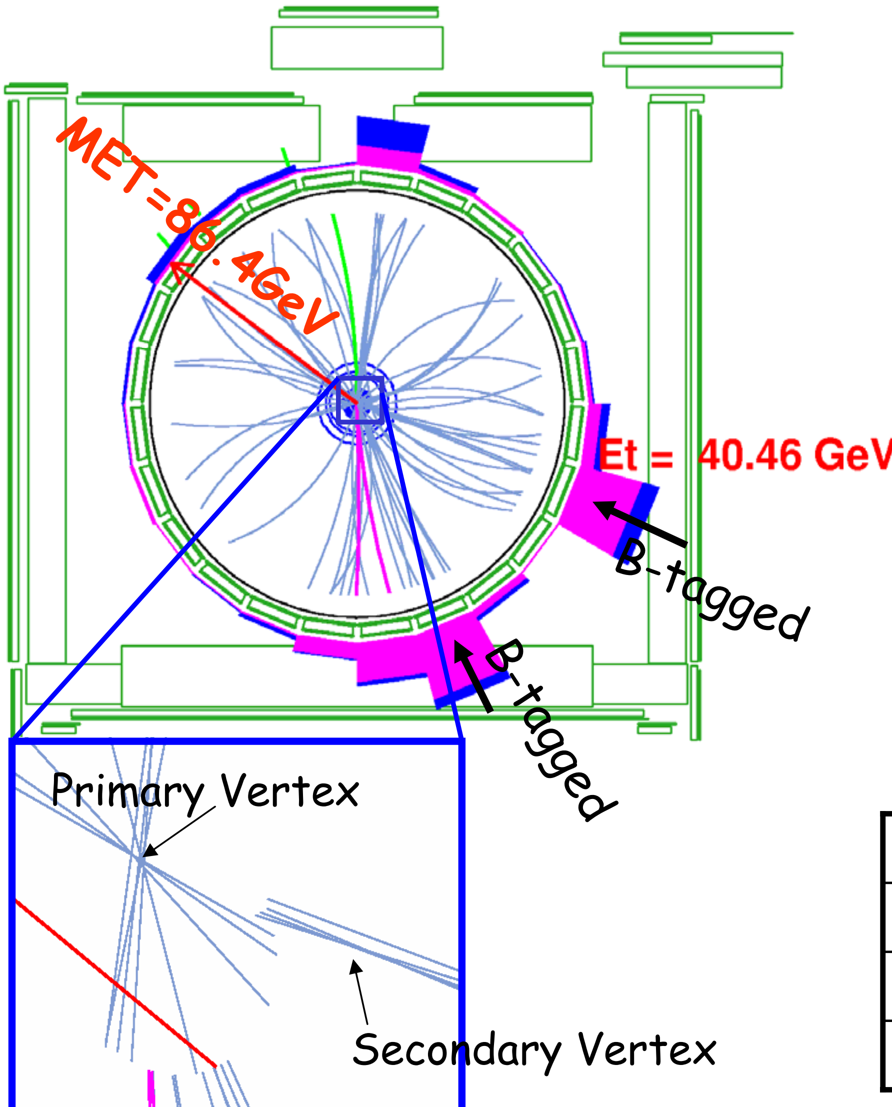


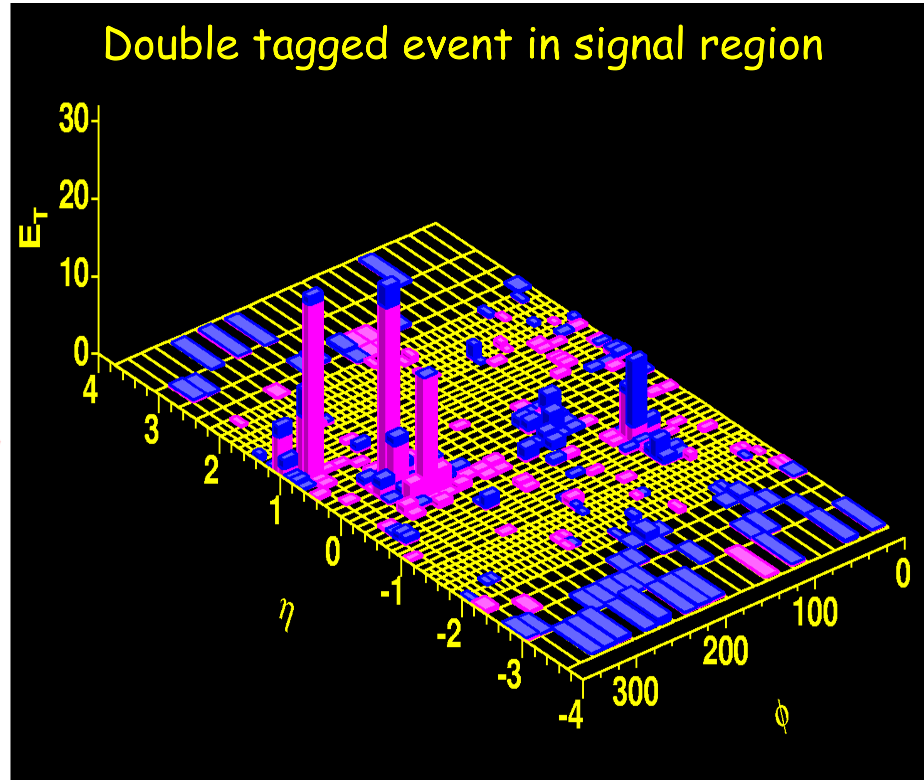
Perform counting experiment

Expected 16.4±3.7
Observed 21

Expected 2.6±0.7
Observed 4

Sbottom Searches

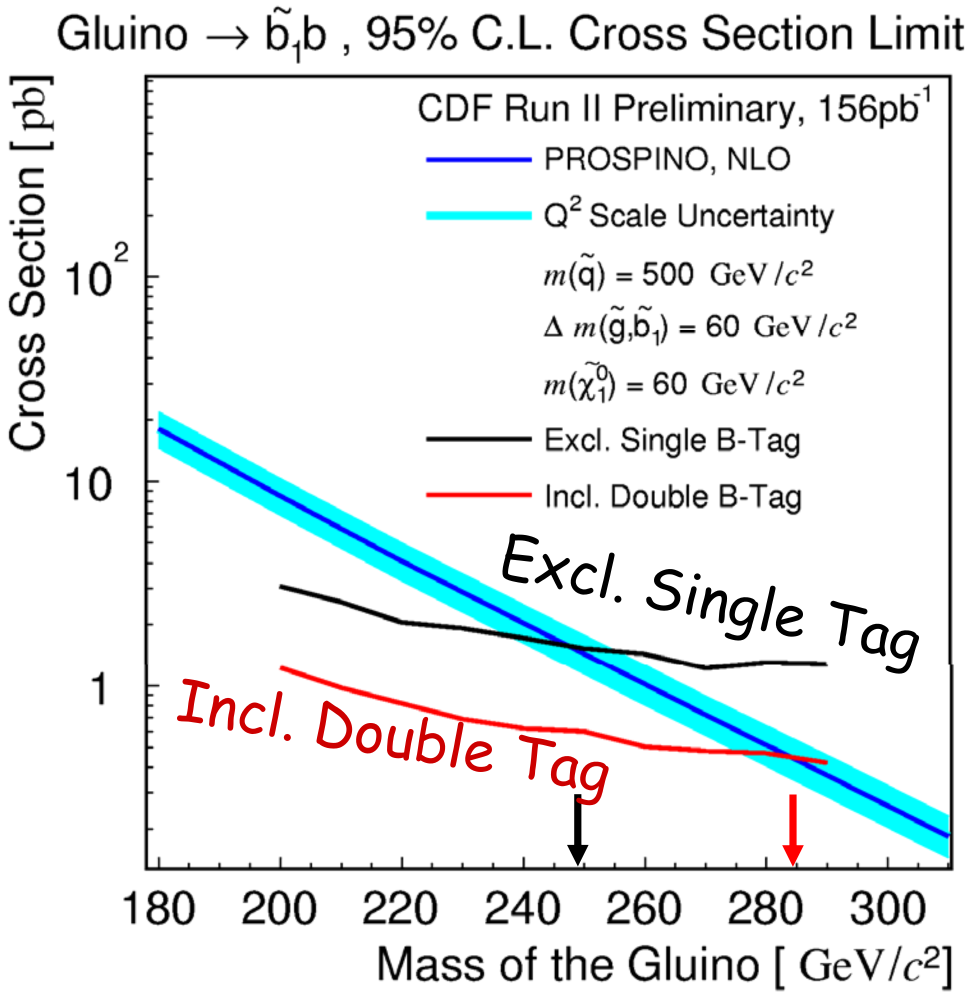




Et	η	ϕ	Tag
85.3GeV	0.02	4.99	1
51.6GeV	0.84	5.97	1
30.0GeV	-0.83	1.42	0

Cross Section Limit

$\Delta M(\text{gluino,sbottom}) = 60 GeV/c^2$



Excl. single tag: Exclude 20.6 signal events at 95%C.L.
Incl. double tag: Exclude 8.7 signal events at 95% C.L.

Upper limit on signal events

$$\sigma^{Limit} BR(\tilde{g} \to b\tilde{b}_1) = \frac{N^{Limit}}{\varepsilon \cdot L}$$

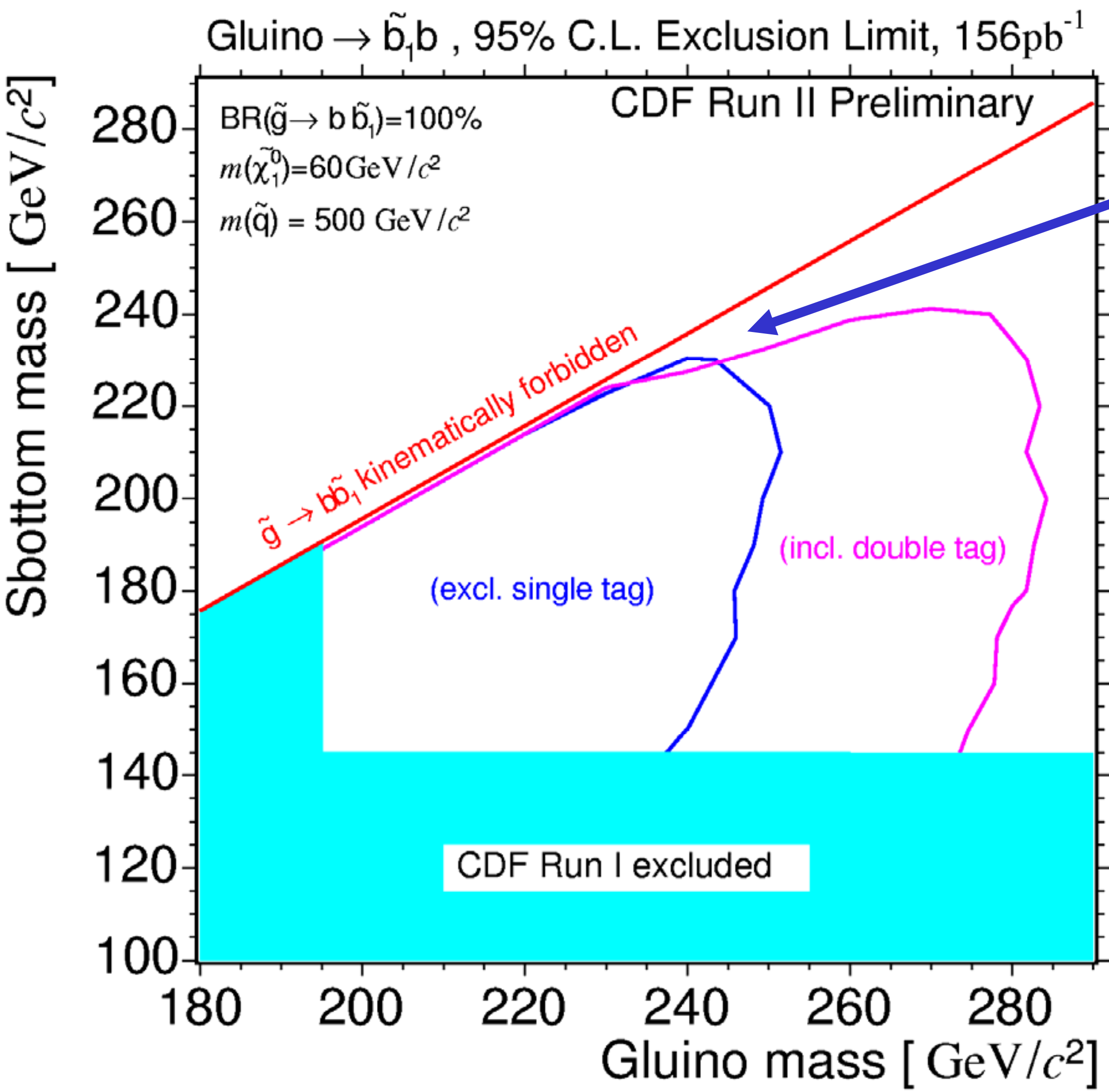
Assume branching ratio 100%

Signal selection efficiency

Luminosity

Now translate upper limit cross section to exclusion plane

Gluino/Sbottom Exclusion Plane



Exclusive single tag analysis more sensitive for nearly mass degenerated scenario

Exclude new parameter space

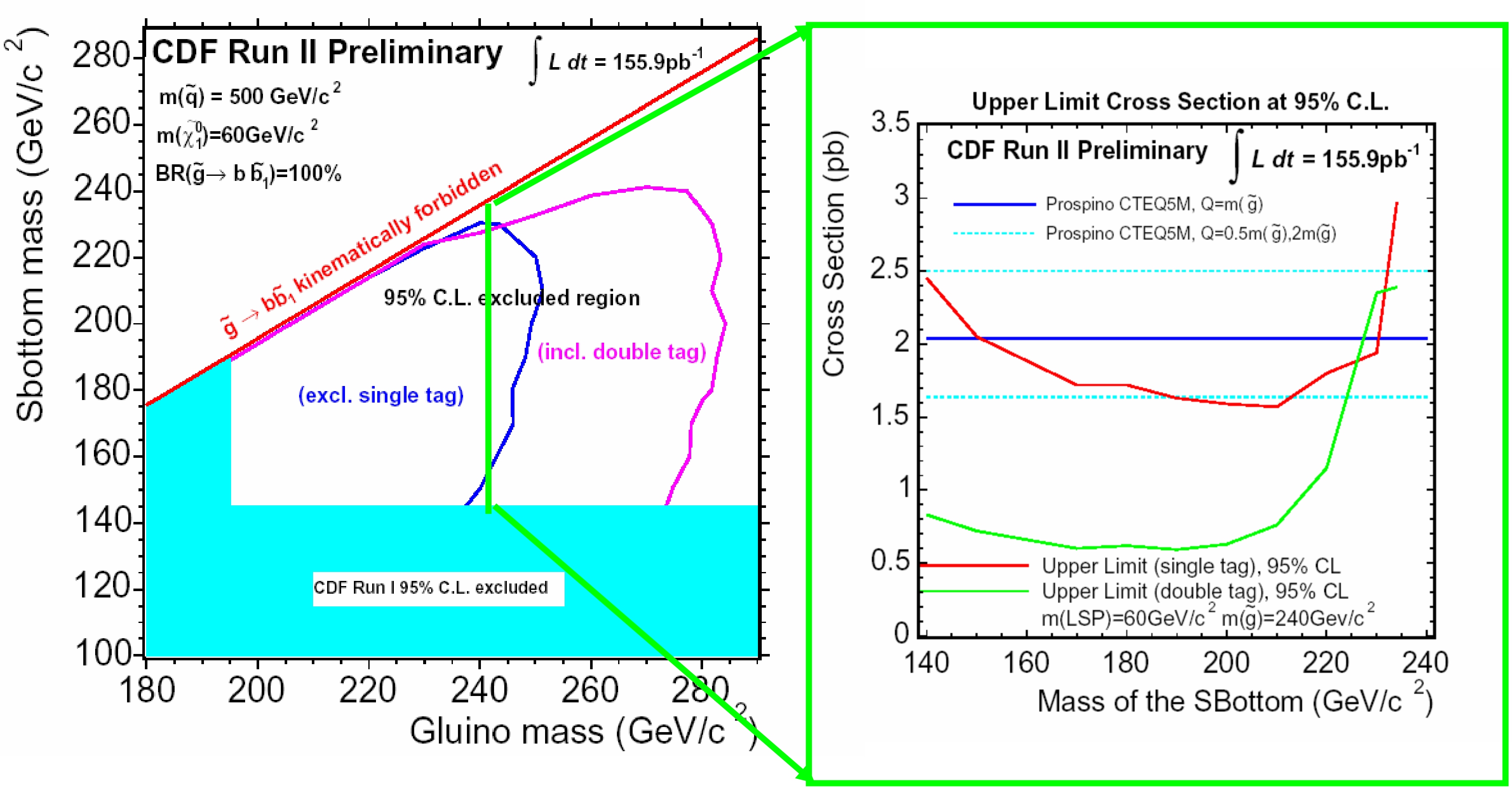
Obtain larger exclusion limit using inclusive double tagged events, due to better background suppression by similar signal acceptance

Similar limits expected also for also for larger neutralino mass scenarios

Conclusions

- Heavy flavor jets and $\not{E}_T$ exciting combination to look for new physics
- Performed search for sbottom quarks from gluino decays
- No excess found and new exclusion limit was set
- Vastly exceed Run I limits
- Searches beyond the standard model are ongoing …
- http://www-cdf.fnal.gov/physics/exotic/run2/gluino-sbottom-2003/bless_plots.html

Gluino/Sbottom Exclusion Plane



Gluino production allows significant extension of the best limits at high mass Sbottom and low mass neutralinos